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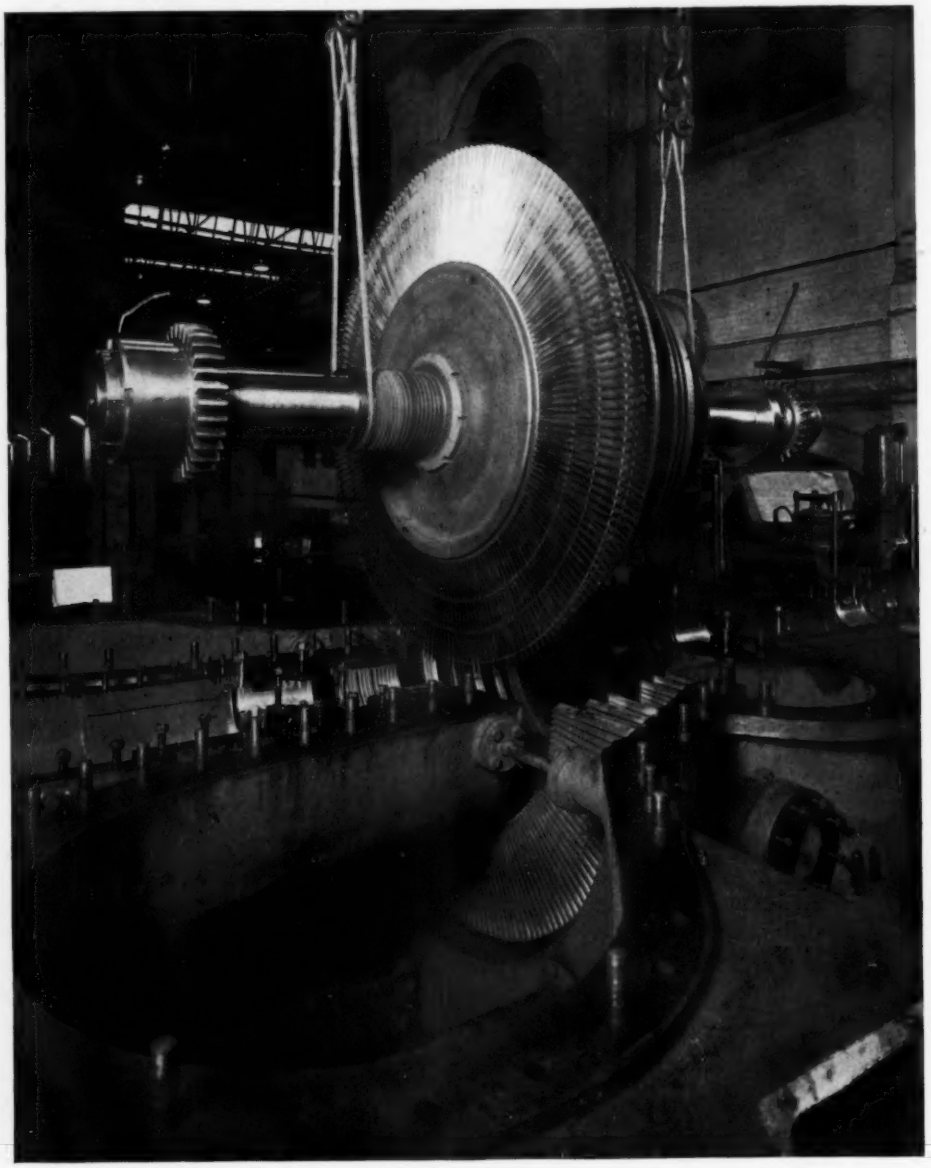

The Company have supplied and have under construction a number of 25,000 kW Pass-out Turbo-Alternator Sets for the U.S.S.R. The illustration shows the low-pressure rotor of one of these machines being lowered into position.

The English Electric Journal

Vol. X. No. 12 DECEMBER, 1945. One Shilling

Pass-out Turbo-Alternator Sets for the U. S. S. R.

Among the many activities constituting The English Electric Company's war effort may be numbered the design and construction of several large power plants for the U.S.S.R. In two cases the Company have acted as main contractors for the complete power station equipment, and in this capacity they have engineered the entire projects, from the incoming water and fuel systems to the switchgear for the outgoing feeders. The provision of water heating plant for district-heating is of special interest.

Perhaps the most outstanding technical feature of these Russian contracts is the supply of six 25,000 kW 3,000 r.p.m. turbo-alternator sets of the pass-out type, two of which are installed in one station. The output of these sets is the largest for which units of this type have hitherto been designed and built in this country.

The economical advantages of the pass-out turbine have been established for many years for plants where large quantities of low-pressure steam are required for industrial processes, and it has a special advantage where the steam demand has to be independent of the electrical load, and *vice versa*.

The essential feature of the scheme under review is that the water heating is done in two stages, "basic" and "peak," two calorifiers being provided for each stage. For the basic heating, steam is taken from the exhaust of the high-pressure cylinder of one of the turbines, and for peak heating, from an intermediate point in the high-pressure cylinder of the other machine. Thus the two sets are dissimilar, and one supplies, at the pass-out branch, a maximum of 220,500 lb. of steam per hour, at a maximum absolute pressure of 26.3 lb./sq. in., while the second set can deliver 330,750 lb. at a higher absolute pressure of 99.5 lb./sq. in. The two basic heaters can supply hot water at a maximum temperature of 240° F., while the peak sections can further heat the water to 275° F.

Both machines can deliver their full electrical loading of 25,000 kW under any condition of pass-out steam, and in addition, facilities are provided for the low-pressure steam demand for water heating—should it be in excess of the high-pressure steam required by the turbine to generate the electrical load—to be supplied from another source. This takes the form of pressure-reducing and desuperheating equipments by the

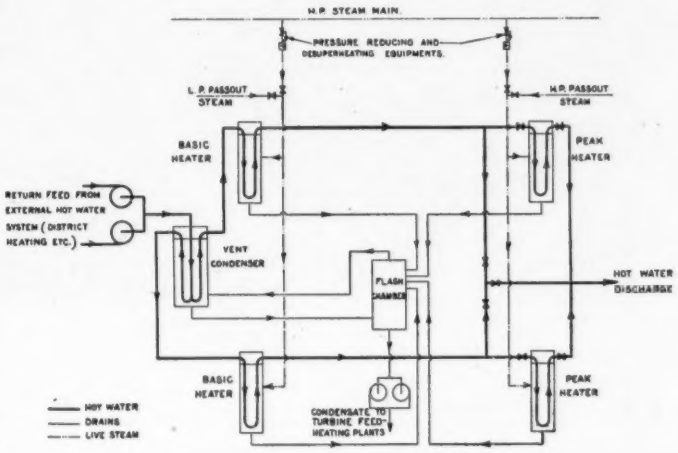

Fig. 1.—Simplified diagram of water heating system.

aid of which the hot-water supply can be maintained even when the sets are shut down.

Fig. 1 gives a simplified diagrammatic layout of the water heating plant connections. It will be seen that the return feed from the water heating system is first pumped into a vent condenser. This is fed from the "flash chamber" into which is taken the drain from the heater units. In this chamber the drainage water flashes into steam due to a reduction in pressure, and the heat in this steam is used in the vent condenser to pre-heat the incoming cold water.

It then passes through the basic heaters, and it may, or may not, be further heated by the peak heaters before being sent out to the hot-water discharge, depending on the conditions required on the external system. The manner in which the auxiliary sources of live steam—the pressure reducers and desuperheaters—are connected to the system is clearly shown in the diagram.

By these arrangements the utmost degree of flexibility is obtained, and this is the special merit of the general scheme.

The pass-through valves—the large volume of steam makes two interlocked valves necessary—are oil-relay operated under the control of the governor, and are so arranged that the steam not required in the pass-out system is returned, as required by the electrical load, to the lower pressure stages of the turbine. The setting of the relay actuating these valves is under the operator's control by means of a handwheel, and this is shown in Fig. 2. Thus all that the turbine driver has to do, in addition to the normal duties appertaining to the turbine running, is to correlate the setting of this handwheel with the conditions in the hot-water system.

Steam Turbines.

Both machines are of the two-cylinder type, and are designed for a stop-valve pressure of 412 lb. to the square inch (absolute), and a steam temperature of 752° F. The high-pressure cylinder is of the impulse design, and the low-pressure side is of the single-flow reaction type. The diaphragms are of the built-up design, the nozzles being formed from separate accurately machined mild-steel segments, built into a centre of similar metal. This construction is shown in Fig. 3. It is thus possible to obtain accurate nozzle profiles with a high standard of finish, and maximum efficiency is obtained. The blading in both cylinders is of stainless iron machined from the solid bar. In order to reduce the effects of wetness at the exhaust end of the low-pressure cylinder, water drainage grooves are fitted in the cylinder in front of the last two expansions. The last two rows of rotating blades are constructed of manganese nickel steel, due to the heavier stresses at that point. To prevent corrosion these blades are chromium-plated.

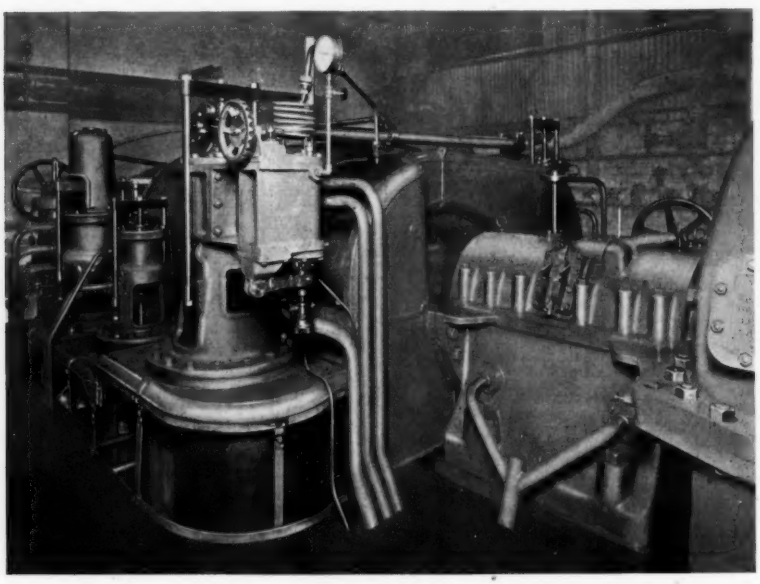

Fig. 2.—The turbine control valves, showing the hand-setting gear for the relay controlling the pass-through valves.

The high-pressure turbine rotor is machined from a solid forging of Siemens-Martin steel, the discs being integral with the shaft. By this construction the maximum rigidity and minimum disc stresses are achieved in that part of the machine where the largest temperature and pressure variations occur. At the exhaust end the larger diameter of the discs necessitates the shrinking-on of

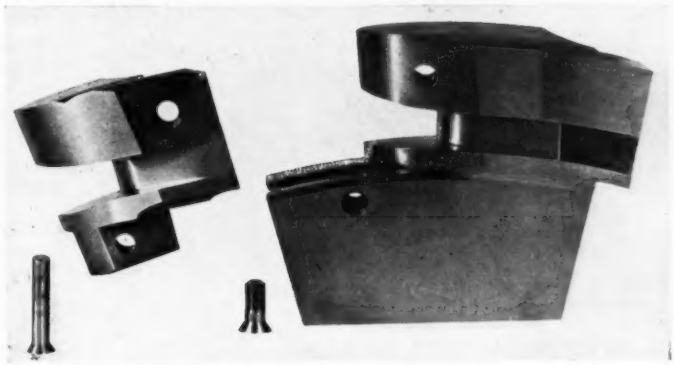

Fig. 3.—Construction of built-up nozzle.

high-tensile alloy steel discs on the low-pressure shaft, and a dummy piston is fitted to balance out the end thrust. Labyrinth glands of the usual type are used.

The main oil pump (of the gear wheel type) supplies oil at a pressure of about 50 lb./sq. in. and from it are fed the governor control valve relays and the lubricating oil supply to the thrust and other bearings of the turbine and the alternator. For starting up under emergency conditions, a turbine-driven auxiliary oil pump with auxiliary relay is provided. The pressure of the oil in the main system applied to this relay causes the pump to start up or shut down when the main oil pressure reaches the predetermined limits.

Motor-operated turning gear is provided, with an arrangement to throw it out of gear when the rotor picks up speed, although normally it is disengaged by hand. A motor-driven jacking pump supplies oil at about 1,000 lb./sq. in. to the alternator bearings for starting up, and a low-pressure auxiliary oil pump supplies the lubricating oil to all the bearings. Automatic tripping of the main steam valve has been arranged for over-speed conditions, and two over-speed safety governors of the unbalanced ring-type are mounted on the shaft end of the high-pressure rotor, one set to trip at 12 per cent., and the other at 14 per cent. above normal speed. In the event of the turbine rotors exceeding the normal speed of 3,000 r.p.m. by the predetermined amount, the unbalanced ring strikes the trip lever which actuates an emergency pilot valve, and this in turn releases the oil pressure in the main stop-valve relay and governing pass-out valve relay, thus automatically shutting down the turbine.

Further emergency features are the provision of local hand tripping, and shutting-down can also be accomplished by means of a solenoid-operated trip from the control board. An oil relay dashpot, controlled by the main oil system, will trip the main stop-valve on failure of oil pressure.

Surface Condensers.

An interesting feature of the condensers is that the water boxes are divided vertically to allow one-half to be cleaned while the other section is in operation, the loading being suitably reduced. This feature is shown in Fig. 4.

They are of the two-flow divided type, and they maintain a vacuum of 27.85 in. (Bar. 30 in.) at the maximum duty; 20,680 gallons of cooling water per minute, at a temperature of 77° F., are required.

Feed Heating System.

Each turbo-alternator set is equipped with a feed heating system comprising one low-pressure heater, one high-pressure heater and a de-aerator heater. The large quantity of make-up water required necessitates the installation of a com-

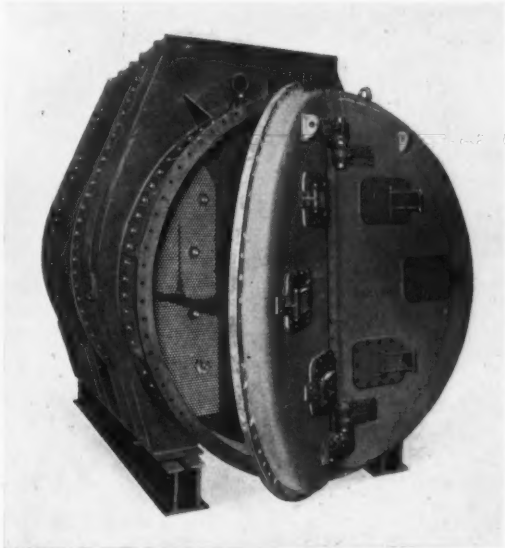

Fig. 4.—The divided condenser of which one section can be cleaned while the machine continues to operate, at partial load, on the other half.

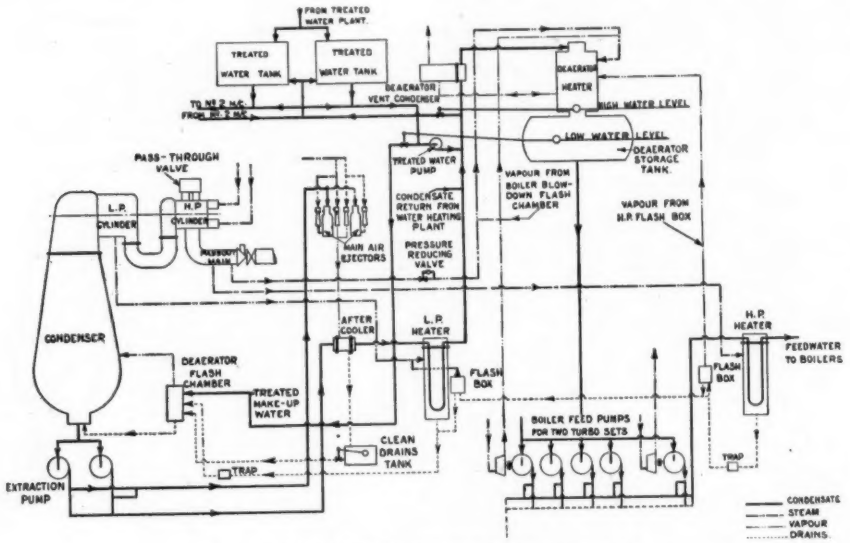

Fig. 5.—Simplified diagram of feed-heating system.

bined lime treatment-base exchange water softening plant in place of the evaporators used on similar installations. This treated water is in free contact with the atmosphere, and will, therefore, contain a certain percentage of oxygen in solution. To remove this the de-aerator heater is introduced.

The condensate flow system, the surface type low-pressure heater, and the other feed heating details follow normal standard practice, and Fig. 5 shows the general layout.

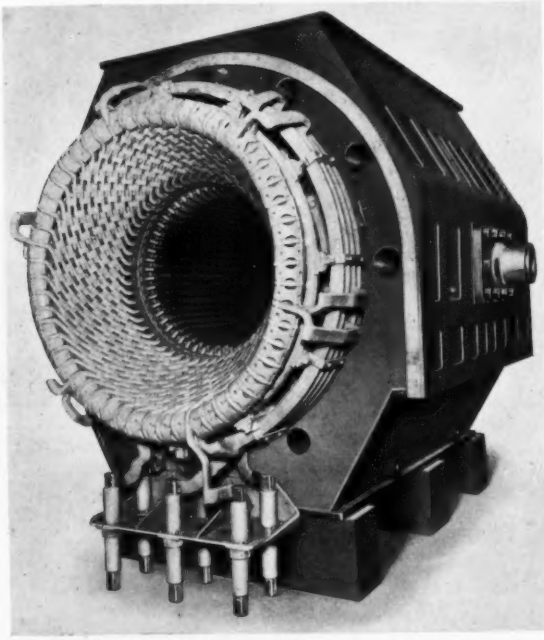

Fig. 6.—Stator of 25,000 kW, 3,000 r.p.m. turbo-alternator.

Alternators and Exciters.

The alternators are designed for a maximum continuous rating of 31,250 kVA at 0.8 lagging power factor. The generated voltage is 10,500 volts, and the system is 3-phase, 50 cycles. The maximum rating can be developed with the voltage varying between plus or minus 5 per cent.

The stator frame is of welded construction, strongly ribbed, and the core, of steel laminations having high electrical resistance and low hysteresis loss, is fitted into dove-tailed grooves integral with the stator frame. The straight portion of the "basket" type stator coils is insulated with pressed mica, and the curved portion with mica tape, while the whole coil is finally wrapped with woven glass tape.

The alternator is cooled by a totally-enclosed air circuit system, the ventilating air being circulated through the machine by fans mounted on the rotor, the discharged air passing through a gilled surface-type air cooler, which takes its water supply from the condenser circulating water system.

The exciter set is directly driven from the end of the alternator shaft and comprises a main and pilot exciter mounted back to back and forming a self-contained unit. A general view of the alternator stator is given in Fig. 6.

The whole scheme forms an interesting example of the work of the Company's Turbine Department in designing and manufacturing, during the war years, an outstanding installation of a special type of steam-driven generating equipment.

Automatic Stud Welding

By A. H. BENT, M.Inst.W., A.M.I.E.E., Manager, Welding Equipment Department.

A development of the well-known arc welding process in the form of Stud Welding has been produced by The English Electric Company. The principle of stud welding is not entirely new, but it is in the application that considerable thought and development has taken place resulting in the production of equipment which now takes its place in the modern science of arc welding.

The equipment constitutes an application of established principles in a different form and, by effecting a considerable amount of saving in time and costs, opens up a number of uses. This plant enables studs to be arc welded to plates or structures so replacing the older method of drilling, tapping and inserting the bolt or blanking the plates and bolting through. This latter process necessitates welding round the head of the bolt where sealing is required against gas, oil, water, etc.

High speed of operation is effected and the quality of the welds is of the highest order.

The essential function of the plant is to arc weld into exact position studs of given sizes by using a pistol-grip tool for the control of the stud, as shown in Fig. 1. The plant is connected to the existing current supply and the voltage is reduced through double-wound transformers to approximately 100 volts on the secondary side. By means of oil-immersed current regulators, suitable timing apparatus and the above-mentioned tool, the current is passed through the stud and the plate, the stud being automatically welded in the correct location. A porcelain ferrule surrounding the base of the stud is usually incorporated in order to prevent contamination of the weld metal by the atmosphere and also to prevent arc splatter. The tool is operated by means of a trigger switch and once the switch is closed the remainder of the operation is purely automatic and controlled by a motor-driven camshaft timing device. The current required for a given size of stud is obtained by selective adjustment of a rotary tapping switch on the current regulator and the necessary timing for this operation is also easily pre-set by means of a rotary handle on the timing mechanism.

On the base of the stud is a small pip in order

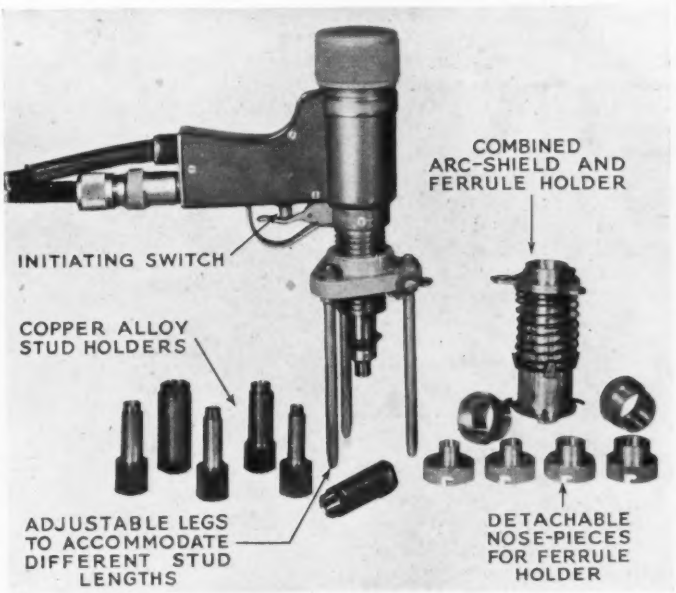
COMBINED ARC-SHIELD AND FERRULE HOLDER
INITIATING SWITCH
COPPER ALLOY STUD HOLDERS
ADJUSTABLE LEGS TO ACCOMMODATE DIFFERENT STUD LENGTHS
DETACHABLE NOSE-PIECES FOR FERRULE HOLDER

Fig. 1.—Pistol grip stud handling tool.

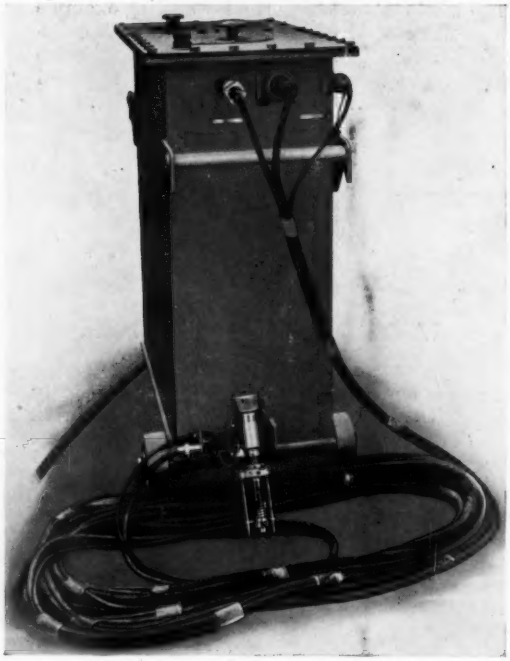

Fig. 2.—Combined A.C. stud arc-welding equipment.

to initiate the arc. The stud is pushed against the plate by means of the tool and when the pip is fused by the passage of the welding current the stud is held in suspension allowing arcing to take place for a pre-determined time, at the end of which time period the stud is plunged into the molten pool. The complete operation takes less than one second. The plunging of the stud forces any surplus metal from the pool and this metal forms into a collar contained by the ferrule. The collar metal may, if necessary, be removed by means of a hollow cutter without impairing the strength of the weld.

In the tool a combined flash damper and ferrule locater is incorporated thus eliminating all external arc flash and splatter. This is a valuable feature as the operator is not required to have any protection against the arc flash and splatter; the parent metal is left clean, and nearby personnel are in no way inconvenienced.

As the complete cycle of operations is automatically taken care of once the " trigger " on the tool is closed, and no skill is required either to load or locate the stud, the process is so simplified that no difficulty should be experienced in using the equipment.

The whole of the equipment is designed on robust lines for operation outdoor in shipyards or constructional work, as well as in heavy and light industries. In general, the main equipment remains stationary whilst the tool may be taken anywhere within range of the cable to operate on the job *in situ*.

The Company is manufacturing a range of automatic stud welding plants to meet various industrial needs, and brief descriptions of three types are given below :—

(1) The straight A.C. equipment illustrated in Fig. 2, is a completely self-contained, oil-immersed unit comprising a transformer, a reactor, timing unit (not in oil), and a primary contactor. The unit is single-phase and may be connected to any 380-440 volts supply. It is mounted on wheels and may be moved within the limits of the primary cable or from one power point to another. Recommended protection on the primary side is by a 100 amp. double-pole fuse switch.

This equipment is designed to weld studs up to $\frac{1}{2}$ in. diameter using secondary leads not longer than 50-70 ft. The limitation of cable length is necessitated by the high reactive drop in long cables due to the fairly heavy instantaneous currents employed.

(2) The rectified A.C. equipment, shown in Fig. 3, is designed to operate from the secondary side of a standard multi-operator, 3-phase arc welding transformer, such a transformer usually

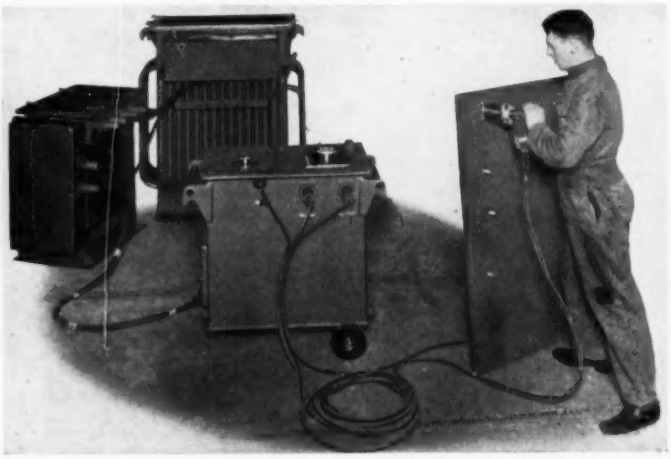

Fig. 3.—Rectified stud arc-welding equipment.

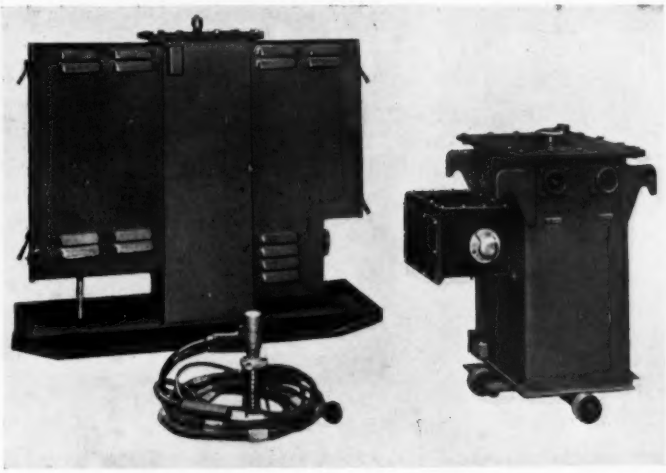

Fig. 4.—The two-operator A.C. stud welding plant.

being available on site. The secondary of this unit is connected by short leads to a 3-phase oil-immersed static rectifier. The rectifier tank also contains the source of supply of 50 volts D.C. for operating the auxiliaries. A second unit, which is mounted on wheels, comprises the current control regulator and the timing device, whilst the same type of stud and tool is used as for the A.C. combined unit.

This equipment is admirably suited for shipyard work as the transformer and rectifier would be located on the shore or at ground level and the control usually located on to the deck, thus complying with the regulations concerning voltages allowed on a ship—the open circuit D.C. voltage being approximately 100 volts.

Length and size of cable still limit the diameter of stud which can be welded, but using .15 sq. in. cable, $\frac{5}{8}$ in. diameter studs can be welded 200 ft. from the transformer. Studs of $\frac{3}{4}$ in. diameter reduce the distance to about 120 ft., whilst smaller sizes allow up to perhaps 500 ft. for $\frac{1}{4}$ in. studs.

It is seen, therefore, that the range of studs may be considerably increased by the use of the rectified type of equipment and, furthermore, non-ferrous studs may be welded equally well—for example, Admiralty Brass.

It is of interest to note that the neutral of the transformer is, as in normal practice, connected to the work and remains at earth potential. The equipment beyond the rectifier is normally "dead," except for the 50-volt auxiliary circuit, and the tool is perfectly safe to handle, the stud only becoming alive when the trigger is pressed to initiate the timing device which in turn controls the rectifier. The tool can, therefore, be handled at all times with perfect safety in the open or in confined spaces.

(3) The two-operator A.C. stud welding equipment, Fig. 4, comprises a single-phase transformer for connecting to a 380-440 volts supply, with a contactor on the primary side and two double-pole interlocked isolators on the secondary side through which two separate current regulators are supplied, each with its own timing device, stud handling tool and accessories. This plant is capable of welding studs from $\frac{1}{4}$ in. to $\frac{5}{8}$ in. diameter and several sets are operating satisfactorily in industrial works.

It will be evident that there are numerous applications for automatic stud welding which while providing the same mechanical strength as the older methods, and being particularly valuable where pressure tightness is required, effects an enormous saving in time with its capacity of 3 to 4 studs a minute for each tool.

Fig. 5 is a macrograph of a $\frac{3}{8}$ in. diameter stud welded in the overhead position, and Fig. 6 shows a number of similar studs welded in the down hand position and bent over to prove the strength of the welds.

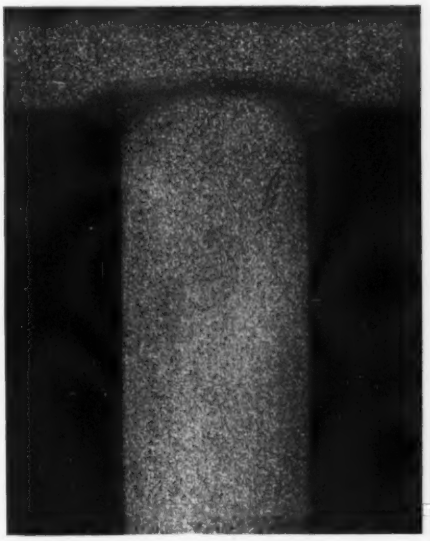

Fig. 5.—Macrograph of $\frac{3}{8}$ in. diameter stud welded in overhead position.

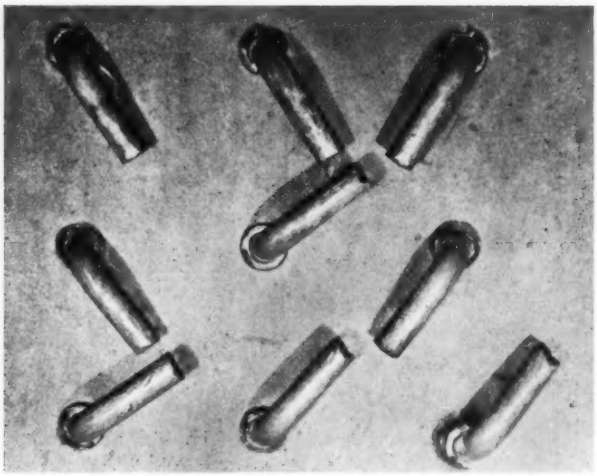

Fig. 6.—Welded studs ¾ in. diameter bent over to test strength of weld.

Studs of recommended standard steel are provided incorporating the necessary pip, and only a very simple change is necessary to the gun-tool to prepare it for a new diameter of stud—no subsidiary tools being required. These studs may be welded to almost any type of steel of thickness ranging from about 16 s.w.g. upwards, provided that reasonable precautions are taken to remove excess scale and rust.

"English Electric" Equipped Diesel Locomotives in the Middle East Campaign

A short time ago Mr. G. H. Paulin, Chief Engineer, Internal Combustion Engine Department, received the following letter from an army man who was one of a group to whom this company gave a special course of training early in the war for the purpose of operating and maintaining "English Electric" equipped diesel locomotives, many of which were used overseas on war service.

"Having worked for three years in the Middle East on diesel locomotives, I want to say here and now, how admirably the "English Electric" locomotives stood up to the stresses and strains of military operation on the desert railway. Certain other diesel locomotives not of British manufacture, which saw much service during the advance from El Alamein, served the purpose but were undoubtedly a war produced job, and after a very short time gave us no end of trouble. The safety devices for over-heating and oil pressure were unreliable but our main trouble was cracked cylinder heads. These locomotives were fitted with very poor governors.

"I cannot praise the "English Electric" locomotive enough. Under the conditions it had to work, such as in violent sandstorms, etc., it gave little trouble and could be certainly relied upon, although handled by some very inexperienced men. It always stood up to the tests.

"I was in the Middle East when the first "English Electric" locomotives arrived. The foreign diesel-electric locomotives arrived late in 1942 and from my maintenance and engineering point of view they were a failure. I was in charge of 14 of them at one time. The breakdowns became so great that steam had to be brought in to help us out while we fitted the diesel-electrics continually with new cylinder heads produced in South Africa. Wherever the 'English Electric' locomotive was working—in all the big transportation stores in the Middle East; in the ammunition dumps at Mersa Matruh in the Western Desert; in Palestine and at Suez docks, they gave us very little trouble. When one takes into consideration the lack of staff for proper maintenance and the climatic conditions, etc., they were really marvellous."

Aircraft Engine Cooling.

By C. D. CARMICHAEL, B.Sc. (Eng.) Development Test Engineer, D. Napier & Son Ltd.

(*Abstract of a Paper read before the Institution of Automobile Engineers.*)

The Magnitude of the Problem.

In considering the heat balance of an internal combustion engine of aircraft type it will be seen that out of every 100 units of heat received, 70 units are rejected in the form of waste heat. Of these 70 units, nearly 50 are accounted for by the engine exhaust, leaving about 20 units to be dealt with by the engine cooling systems. It will be seen, therefore, that the amount of heat to be dissipated is about two-thirds of the gross power output of the engine. An additional requirement is that the combustion chamber surfaces must be kept below their critical temperatures.

Aircraft engines are often loosely described as either air-cooled or liquid-cooled, but a more correct distinction would be to refer to them as directly-cooled and indirectly-cooled types respectively, as in both cases the final cooling problem is that of removing heat from a metal surface by passing an airstream over it.

In an effort to reduce the resistance or drag set up by the radiating surfaces of both types of engines, " ducted cooling " was introduced about the year 1936, and the war years have seen a tremendous advance in its application.

The Theory of Ducted Cooling.

Cooling effect is proportional to the speed of cooling air whilst the drag of any surfaces used to dissipate heat varies as the square of the speed. Thus to reduce the drag to a minimum the velocity must be kept low. To attain this the air is constrained to enter a duct of suitable shape where it is expanded before entering the radiator at a reduced velocity. This slowing down process must be achieved without loss of energy and this can only be accomplished by a very careful study of the shape of that part of the duct before the radiator ; failure to do so resulting in breakaway of the boundary layer with a consequent loss of energy due to the setting-up of eddies.

After the air has passed through the radiator it must again be speeded up so as to rejoin the external air at a speed not lower than the prevailing flight speed, again in order to avoid energy losses. Luckily this presents a simpler problem than the slowing down of the air as it is only in an expanding passage that breakaway and eddying occur.

To complete the story there is the possibility of a slight gain in propulsive energy from the duct for the following reason.

Assuming that the air is slowed down without loss the pressure will rise in accordance with Bernouilli's Equation. At this relatively high pressure the heat dissipated by the radiator is added and this pressure energy is converted into kinetic energy as the air is speeded up towards the exit from the duct. Thus the whole effect may be referred to as a very mild form of jet propulsion. At the higher flight speeds this propulsive effect becomes more efficient and may balance or even exceed the drag due to skin friction inside the duct.

Before the introduction of ducted cooling the cooling drag due to fully exposed radiators was as high as 10 per cent. of the B.H.P. in some installations.

The application of the mechanism of boundary layer suction to cooling ducts is extremely interesting and worthy of consideration, but it is beyond the scope of this short article.

Air-cooled Engine Problems.

In this type of engine the heat transfer takes place directly from the cylinder barrel and head to the airstream. To increase the radiating surface, fins are provided which have to fulfil two requirements, that of providing maximum heat dissipation coupled with minimum weight and bulk. With the stepping-up of engine powers fins have increased in height and in number, but there is a limit to both these developments, which has now been reached. Beyond a certain height the rate of heat dissipation falls off rapidly and, in addition, very deep fins are almost impossible to machine. The closeness of pitch of two adjacent fins is, furthermore, governed by the interference of their respective boundary layers. Further developments are likely to be confined to improvements in heat conductivity by the use of different materials, particularly for the cylinder head, which always presents the most difficult cooling problem.

In order to provide for equal expansion the fins on the exhaust side of an air-cooled cylinder are often more generously proportioned than those on the relatively cool inlet side.

Alternatively, baffles are sometimes affixed around the exhaust fins in order to increase the velocity of the air-flow locally. In fact, by the prodigal use of baffles coupled with efficient engine cowling the air-cooled engine is now reducing the gulf which formally separated it from the liquid-cooled engine in respect of cooling drag.

In recent years fan-assisted cooling has come into prominence. Initially introduced to improve cooling on the ground, it is now thought to be desirable for climbing conditions particularly at high altitude. The fan is fitted immediately behind the propeller, at the entry to the cooling duct, and is driven at engine speed approximately. A recent development is the provision of fan blades on the propeller spinner, this having the advantage of simplicity.

Fundamentally the air-cooled engine presents a much more difficult cooling problem than its liquid-cooled counterpart and for that reason the latter engine will always be capable of producing higher specific outputs.

On the one hand there is a certain freedom of choice in the external shape of a liquid-cooled cylinder and its radiator can be proportioned to best advantage. The radiator of an air-cooled engine is, however, the external shape of the individual cylinders and it is difficult to believe that this shape is ideal from the cooling point of view.

Pressure Cooling Systems for Liquid-cooled Engines.

Of necessity, due to the indirect nature of the cooling of this type, its cooling system is more complex and consists of the following essentials :—

(*a*) Cooling jackets surrounding the cylinders.
(*b*) Header tank.
(*c*) Radiator.
(*d*) Circulating pump.

In considering the design of cooling jackets, good control of coolant flow throughout is essential and there should be no stagnant pockets. Local restrictions should be provided near the hotspots to ensure efficient scrubbing of the hot surfaces and thus prevent the formation of steam pockets which can be extremely dangerous especially if they occur in a part of the cylinder block which is difficult to vent.

Before the introduction of pressure cooling systems, " open " cooling systems were in use and the header tank was open to the atmosphere. In such cases the maximum temperature of the coolant must be less than that at which boiling occurs at the prevailing atmospheric pressure. As the boiling point of water is lowered at altitude, a limit is set to the temperature difference between the radiator and the cooling air resulting in the use of excessively large radiators especially on engines which maintain their power up to high altitudes.

The high temperature or pressure cooling system, now in universal use, has overcome this limitation by employing a " closed " system in which the pressure can be raised above that of the surrounding atmosphere. The coolant temperature can therefore be increased beyond its normal boiling point, provided that the pressure at every point in the circuit exceeds by a safe margin (at least 5° C.) that at which the liquid would boil, at the prevailing temperature.

Fig. 1 shows a typical pressure cooling system in which the header tank is placed at the highest point.

This header tank serves the following functions and provides :—

(*a*) A reserve of coolant.
(*b*) An expansion space for the coolant.
(*c*) A suitable place for separating vapour from the coolant.
(*d*) The pressure control point.

The first two provisions need no explanation, whilst item (*c*) is required because of the need for maintaining the liquid circulation rate and avoiding vapour locks, centrifugal means being used to separate the liquid from the vapour.

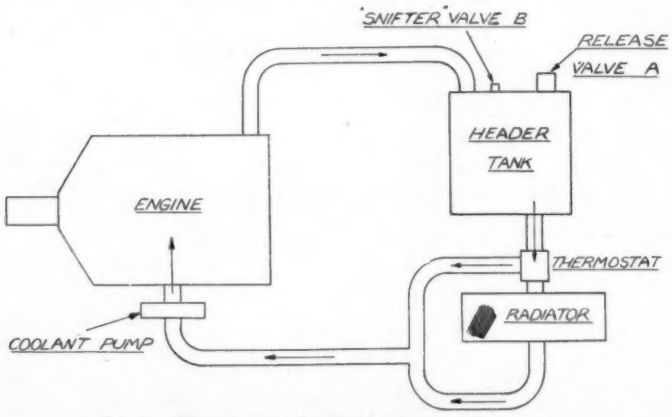

Fig. 1.—Diagrammatic layout of pressure cooling system.

The fourth provision is the most important as it is within the header tank that the superimposed pressure is controlled by means of the release valve (A) and the snifter valve (B).

The danger point in this system exists at the entry to the coolant pump where the pressure and temperature have the lowest values. The pressure at the pump inlet can be increased by the use of venturi-injectors supplying " make-up " coolant from the reserve in the header tank.

The Principle of the Functioning of a Pressure Cooling System.

If the pressure and temperature of the coolant in the tank are adjusted so that boiling takes place, the vapour so formed will increase the pressure in the air-space, and therefore throughout the whole system, since the tank is closed. This boiling will continue until the pressure reaches the saturated vapour pressure. The tendency will then be for the vapour to condense and so lower the pressure but this will induce further boiling and so a state of equilibrium will be produced.

Thus the header tank becomes the control point of the system and to avoid damage due to excessive pressure a relief valve (compensated for altitude) is provided in the tank. This valve is set to blow-off at a pressure a few pounds in excess of that existing between the inside of the header tank and the external atmosphere at the maximum power altitude of the engine-aircraft combination. If the pressure in the tank falls below that of the external atmosphere the snifter valve opens and restores the pressure, this valve being required to prevent the collapse of the tank due to high negative pressures.

Radiator Suitability.

The radiator size is determined from the heat loss figures quoted by the engine builder and is designed to dissipate sufficient heat at the climbing output of the engine to maintain the coolant temperature below the maximum safe figure. Radiator suitability is assessed by making test flights and correcting the coolant temperatures recorded for either "English Summer" or "Tropical" conditions dependent on the use for which the aircraft is intended. One of the most important results of the introduction of pressure cooling has been the effect on radiator size, and the higher temperature difference between the radiator and the airstream allows a smaller radiator to be used for the same heat flow. The actual coolant used universally is a 30/70 mixture of ethylene glycol and water, the glycol being added chiefly as an anti-freezer, although it does raise the boiling point curve by some 3° C., and this again permits the use of a slightly smaller radiator than when water is used alone.

During long glides the coolant temperature drops and causes thermostats to open which allows the coolant to by-pass the radiators. By this means the minimum coolant temperature most suitable to the particular engine may be maintained.

Coolant Pumps.

Centrifugal pumps are used universally and those on the "Sabre" engine, which are two in number, have fully-shrouded rotors with carbon-type water seals. Each pump, which rotates at 1·228 times crankshaft speed, is capable of pumping 200 gallons/minute against a pressure head of 60 lb. sq. inch. Great importance should be attached to the inlet connection to the pump as this is the critical point in the whole system. If incipient boiling and vapour lock are to be prevented, sharp bends adjacent to the pump inlet should be avoided and the use of venturi-injectors to increase the pressure at this point is, as mentioned previously, an important factor.

The Influence of Oil Cooling.

All aircraft engines get rid of some of their waste heat through the agency of the lubricating oil, and the amount of heat so removed may be as high as one-quarter to one-third of that removed by the coolant.

Whilst the coolant operates in the region of the cylinder barrel and cylinder head the oil is responsible for cooling the following parts of the engine :—

(*a*) The underside of the piston.
(*b*) The piston crown (partly) via the piston rings.
(*c*) The crankcase end of the cylinder walls.
(*d*) The crankcase.
(*e*) Reduction gears, etc.
(*f*) Supercharger clutch.

Oil-cooling System.

Space only permits of a brief review of the oil-cooling system which is similar to the coolant system in some respects, consisting as it does in the following essentials :—

(*a*) Oil scavenge pump.
(*b*) De-aerator.
(*c*) Oil cooler.
(*d*) Oil tank.

The oil scavenge pump delivers oil from the engine sump through a de-aerator, which removes most of the air entrained by the pump to an oil cooler which in the case of a liquid-cooled engine is usually situated in the main cooling duct, together with the coolant radiators.

Lubricating oils are by no means easy to cool as the rate of heat transfer is only half that of water; consequently cooler design is quite a complicated business. Oil cooler passages must not be too small otherwise they will be blocked completely by cold oil, contrariwise too large passages cause the hot oil to flow through the centre of the passage only, being protected from the cool walls by a thick layer of congealed oil.

Conclusion.

In this short article no attempt has been made to enter into the argument of air-cooled versus liquid-cooled types but the following comment is offered.

Much of the pre-war prejudice against liquid-cooled engines for civil aircraft was due to indifferent "plumbing" but this objection is no longer valid.

The English Electric Company's War Activities Exhibition

A Gigantic Transition from War to Peace

Fig. 1.—The Showrooms of The English Electric Company at Queen's House, Kingsway, London, where the War Activities Exhibition attracted over 20,000 visitors.

The English Electric Company's "War Activities" Exhibition, opened to the public on November 19th, for four weeks, at their London showrooms, Queen's House, Kingsway, showed, in miniature, how the Company's four works at Stafford, Rugby, Bradford and Preston met the country's needs by turning out seventy-five million pounds' worth of wartime products in addition to an increased output of normal equipment.

The basic method adopted at the exhibition was to show the story of the war in a series of striking illuminated panels, while at each stage the Company's contribution was demonstrated by photographs and models.

As early as 1936 the Directors of The English Electric Company approached the Government and offered the services of their organisation for the urgently needed rearmament programme. Directly war had been declared, orders poured in for every conceivable wartime need, and among the earliest were equipment for ship propulsion and protective devices for the battle against the magnetic and acoustic mines. A 3-pole air-break circuit breaker of the type largely used in minesweeping craft was shown.

The Company's A.C. arc welding equipment was used very largely in war factories, shipyards and tank production centres, and an example stood near the photographic panels showing this work in progress.

In the spring of 1940, when the Germans invaded Belgium and the Low Countries, the Company urged forward the production of hydro-electric units and large rectifier plants to feed vital new aluminium factories. At the same time their Preston Works undertook the construction of Hampden and Halifax bombers, and the first Hampden was delivered to the R.A.F. only 15 months after the initial order was placed. Photographs showed these activities.

The air battles, including the Battle of Britain, intensified the need for such equipment as sound locators and searchlights, of which a No. 3 Mk. I Predictor, and the mechanism of a large searchlight, are examples.

Tank Production.

A striking sequence of photographs showed tank production shops at Stafford, where large

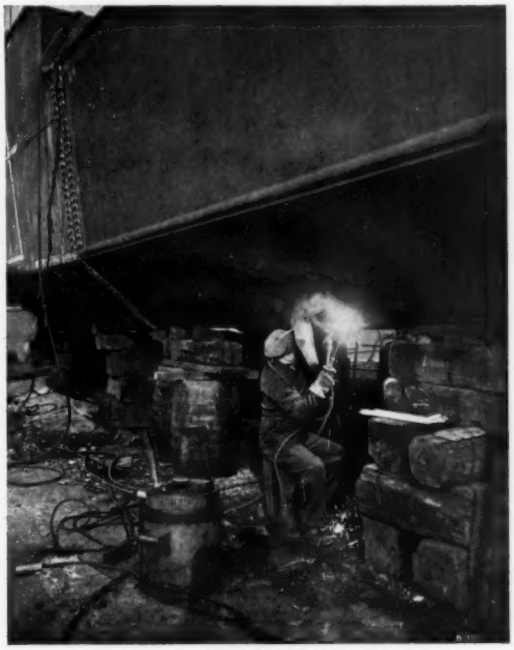

Fig. 2.—Welding the hull of a naval craft with "English Electric" A.C. arc welding equipment.

numbers of Covenanter, Centaur, Cromwell, and later Comet tanks were made by novel methods.

The North African war demanded transport and power facilities in addition to enormous quantities of war material. The English Electric Company supplied the type of diesel-electric locomotives and power stations mounted on railway trucks which were pictured on these panels.

The next series of photographs showed examples of some of the turbo-alternators, transformers, motors and other equipment supplied to the U.S.S.R.

For use on all battlefields which at that time were in active engagement, the Company supplied vast quantities of communication equipment, and a number of examples of transformers, including some of the smallest radio type, were shown.

The standard types of fusegear and allied products, which for many years have been supplied to industrial users, were also in constant demand, and some examples of high-rupturing capacity cartridge fuses were exhibited.

Tens of thousands of aircraft instruments were manufactured, and some interesting examples of these were on view, including the course-setting bombsight, and a number of special motors and generators.

Rapid Delivery of Bombers.

In April, 1940, The English Electric Company received an initial order for 200 Halifax four-engined bombers, and in 18 months, without any outside help, the first Halifax was ready for delivery, a unique feat in engineering. Until the end of the European war, the Preston Works alone produced over 3,000 Hampden and Halifax bombers.

Die-casting technique was developed and extended in the Company's works, and innumerable examples were made for all branches of the Services. A few were shown at this point.

The Stafford Works of the Company developed the technique of all-welded tank assembly, and the Comet tank was one of the most successful

Fig. 3.—Fitting the gun turret to a "Comet" tank at the Company's Stafford Works.

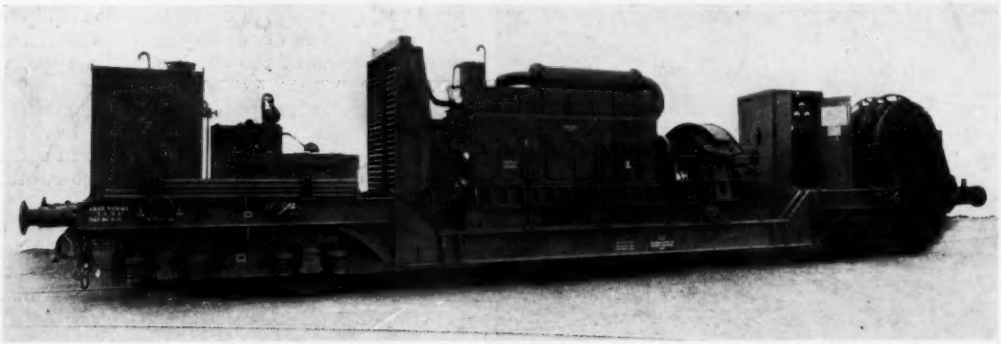

Fig. 4.—One of the mobile diesel-electric power stations built by the Company. These served our armies in Egypt, Libya and Persia.

used by any army, proving one of the decisive factors in the closing stages of the European war. Photographs showed the assembly lines and other details of this tank, while a fascinating model, built by an associated company, D. Napier & Son, Ltd., and made to one-sixth normal size, was on view, with the tracks driven by moving belts. Other models included a 5 ft. wing-span miniature Halifax bomber, together with a small scale model of the De Havilland Vampire jet-driven aircraft, of which the first examples were produced by the Company at its Preston Works, where the whole of the production planning for this unique machine took place.

Next came a special section, the walls of which comprised some striking murals of the Company's works, and the wartime expansion was shown graphically.

Vivid photographs illustrated the care taken by the Company to ensure the welfare of its 25,000 workers, and canteen, medical, recreational, and vocational training services were demonstrated.

Ready for Peace.

The visitor's attention was then directed to the enormous range of the Company's peacetime engineering work, and photographs depicted the workshops at Stafford, Preston, Rugby and Bradford, together with examples of their products. A test wheel for impulse turbines for hydro-electric schemes was shown, and a quarter-size " Straightflow " hydraulic valve was also a prominent feature. Numbers of the smaller sizes of the Company's standard and special motors were on view, one of which was equipped with an electro-magnetic coupling recently developed.

A striking overhead picture welcomed the visitor to a section which might be described as the Company's approach to the future. They have always realised that research is the basis of all progress, and have maintained at Stafford and at their other works up-to-date research stations, staffed by men of high scientific attainments who are also able to apply the results of their discoveries to practical purposes.

A cathode ray oscillograph, which is widely used to photograph and analyse transient phenomena of every kind, was shown in action, and its aid in " strain-gauge " measurement, a technique used in aircraft manufacture, was demonstrated. An industrial X-ray unit, capable of penetrating up to $1\frac{3}{4}$ inches of solid steel, or 8 inches of aluminium, which is used for the detection of errors in assembly and general industrial research and control, was shown in operation, together with some interesting illuminated slides of typical uses of the X-ray plant.

A miniature high-frequency heating equipment was installed, which could be operated by visitors, and also greatly enlarged micro-photographs of sections through welded structures. Typical sectioned examples of arc and stud welding accompanied this exhibit.

An experimental plant for the laboratory preparation of synthetic resins was seen at work, and a large scale model of the high-voltage laboratory at Stafford formed the largest exhibit in the research section. Here again, visitors were invited to use the press button, which caused a miniature flash-over.

Again looking to the future, the Company has wide-spread training schemes for its junior personnel, and photographs indicated the thoroughness with which these schemes are carried out.

Peacetime production was summed up in a bold example of photomontage, in which every field of the Company's activities was photographically demonstrated.

The windows, facing on to Kingsway, showed a detailed model of one of the four 30,000 kW. turbo-alternators at Little Barford, some examples of the Company's prototype " Ritemp " Domestic Appliances, and a large diorama of the Galloway Hydro-Electric scheme, which is especially topical in view of the interest in Scottish water power at the present time.